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e on the van der Kolk method of determining refractive indices.

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[Read November 6, 1941.]

is well known that in the Schroeder van der Kolk[1] method of comparing the efractive index of a crystal grain with that of the material in which it is nted, the effect can be reversed by moving the microscope sub-stage con- er, and that the position of this condenser must therefore be carefully rolled if ambiguities in the interpretation of the observations are to be ded. This fact is mentioned in the majority of text-books and is referred to general manner by Wright[2] and by Winchell.[3] No clear explanation of the ssal is offered, however, and students are consequently inclined to forget this rtant limitation in the method or, alternatively, to forget in which sense the ment of the condenser influences the effect: unless a control experiment is iably performed errors may therefore result. A simple application of ele- ary optical principles to the effect is an instructive exercise, serving to fix in the phenomena which will occur under any set of conditions and at the same to make clear the conditions most favourable for the success of the method.

e effects observed when a crystal grain is viewed in light incident obliquely onveniently explained by assuming the grain to be roughly lens-shaped. The then acts as a converging or as a diverging lens accordingly as it is immersed medium of lower or of higher refractive index than itself, and a parallel beam ht is deflected in the two cases as shown in figs. 1*a* and 1*b* respectively. In r case the ray *BP* is roughly parallel to the axis of the microscope and ges from the eyepiece, while *AQ* is travelling so obliquely that it either does nter the objective or is absorbed by the walls of the tube before reaching the ece. The edge *B* therefore appears illuminated while *A* is in darkness. The al train of the microscope forms an image which is, of course, reversed relative e object on the stage, so that the *image* appears illuminated on the side from the light is incident or on the opposite side according as the refractive of the grain is higher or lower than that of the mounting medium.

hough the above argument has been developed in terms of the whole grain lear that it could be applied equally well to each boundary separately, the

1. C. Schroeder van der Kolk, Tabellen zur mikroskopischen Bestimmung der Mineralien rem Brechungsindex. 2nd edit., Wiesbaden, 1906.
2. Wright, The methods of petrographic-microscopic research. 1911, p. 94.
3. N. Winchell, Elements of optical mineralogy. 5th edit., pt. 1, 1937, p. 79.

only necessary assumption being that the grain boundaries are tapering. Th point is of importance in considering the case of a microscope fitted with co denser, for then the conditions of illumination may differ in different parts of t field of view, so that opposite boundaries of an extended grain may not sho equally marked effects.

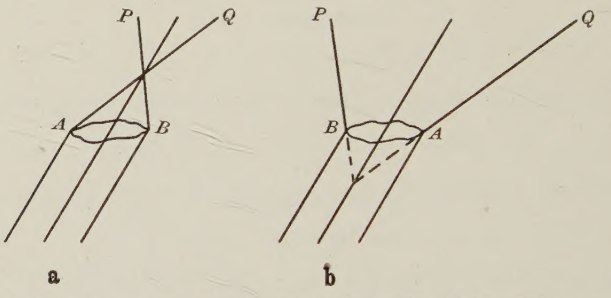


FIG. 1. Path of light rays through a lenticular grain: (*a*) in a lighter medium; (*b*) in a denser medium.

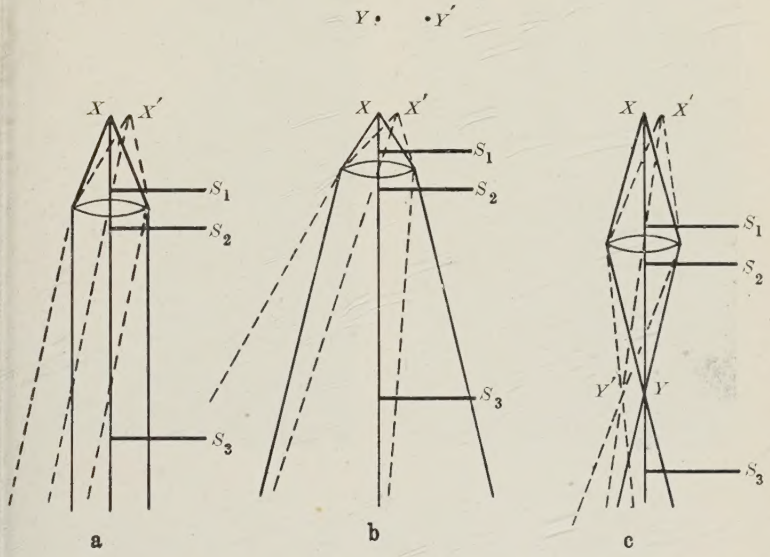
Microscope without condenser.

Let us consider first the case of a microscope having no sub-stage condens In this case conditions approximating closely to those shown in fig. 1 can realized by removing the polarizer and swinging the mirror to one side. The eff is then very pronounced and will be the same and equally pronounced at points in the field of view, especially if a small source of illumination is employ If an extended source is used the oblique light can be obtained alternatively retaining the mirror in its central position and covering part of it with an opa screen. It should be noted, however, that this method is rarely satisfactory, si the mirror subtends at the stage only a relatively small angle and the obliquity rays even from the edges of the mirror is not very marked. Especially is this case when the polarizer is in position and the mirror is necessarily at so distance from the stage. Under these conditions the introduction of a screen only have the effect of obscuring the sensibly parallel light reaching part of field without greatly influencing the obliquity of that reaching the part wh remains illuminated. It is not therefore in general satisfactory to use the Schroe van der Kolk method on a microscope without sub-stage condenser unless polarizer can be removed and the mirror swung some distance to one side; this limitation should be clearly recognized. If observations in polarized light required the analyser can, of course, be used.

Microscope with condenser.

When a sub-stage condenser is employed conditions are completely chan It is now only necessary to remember that all light reaching a single point X the stage will, before refraction by the condenser, have passed through a sec point Y, X and Y being conjugate points with respect to the lens system of condenser. If the condenser is accurately focused on the slide, Y is at infinity a beam of initially parallel rays is condensed to X (fig. 2*a*). If the object

in the focus of the condenser the point Y is virtual and the illumination at X rrived from an initially convergent beam (fig. 2*b*). If now a screen is inserted $_1$, S_2, or S_3 it will clearly intercept the light reaching X from the right so that conditions of illumination of the grain are now similar to those illustrated in l obtained by using parallel light and an inclined mirror. Which side of the n appears to be illuminated is then determined as before by the relative ctive indices of crystal and mounting medium.



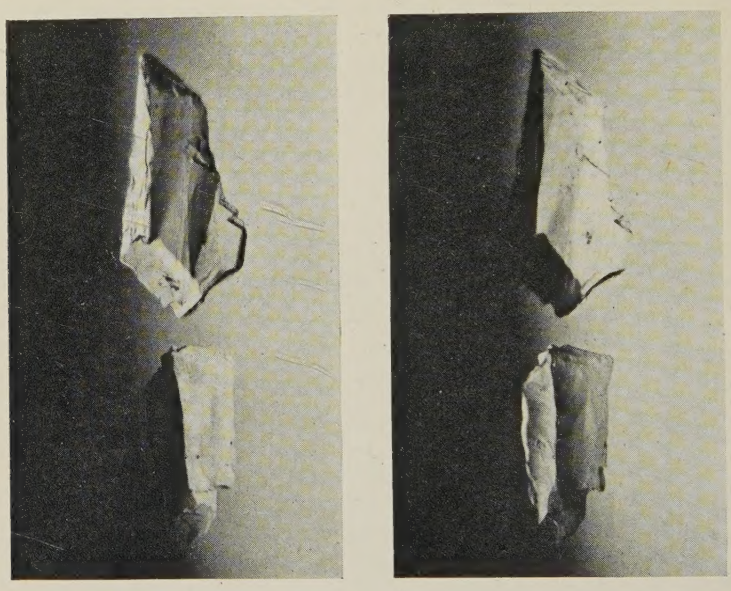
. 2. Illumination of points on the stage with the condenser: (*a*) in focus on the stage; (*b*) raised; (*c*) lowered.

t us now consider the effect of lowering the condenser so that the object X is derably above its focus (fig. 2*c*). A screen placed at S_1 or S_2 will, as before, ff light reaching X from the right, but if the screen is placed at S_3 conditions precisely reversed and light from the left will be intercepted. It is clear that transition between these two conditions will take place when the screen pies the position Y, and that in this position a sharp image of the edge of the n will be visible in the microscope.

the distance through which the condenser is lowered be carefully regulated, n be adjusted to be at a convenient distance of, say, a few centimetres below condenser, and the reversal of the effect obtained by placing the screen first e and then below Y, the condenser remaining unmoved, can then be clearly rved. Alternatively, if the screen is inserted at S_3 and the condenser is then red, a position will be found in which the image of the screen is sharply sed and on further lowering of the condenser the reversal will again be ob- d.

e photographs shown in fig. 3 were obtained in the latter manner. The r grain is fluorite and the lower quartz, with refractive indices of 1·43 and respectively, and the mounting medium is an oil of refractive index 1·50.

For fig. 3*a* the condenser was raised as high as possible and a screen was intr duced from the right in a position corresponding roughly to S_3 of fig. 2*b*. Light therefore falling on the left-hand side of each grain and accordingly the quar



(*a*) (*b*)

FIG. 3. Fragments of fluorite (upper) (n 1·43) and quartz (n 1·55) in oil (n 1·50). Screen inserted below condenser from right. (*a*) Condenser raised; (*b*) condenser lowered.

appears illuminated on the right, the fluorite on the left. (The optical train of t camera produces an image reversed compared with that observed in the micr scope, and therefore of the same sense as that which would be seen if the slide w viewed directly with the naked eye.) For fig. 3*b* the screen occupied the sa position, but the condenser was lowered to correspond to the condition shown fig. 2*c*. It will be seen that the illumination of the two grains is now reversed.

Some further points calling for attention arise when several crystal grains different parts of the field of view are considered simultaneously. We have se above that for the Schroeder van der Kolk effect to be observed it is necessa that the screen should eclipse part, but not all, of the light reaching the gra considered. This may be expressed alternatively by saying that the grain mu lie within the penumbra of the image of the edge of the screen as seen in t microscope. The breadth of this penumbral region under different conditio may be determined by considering the light reaching a point X' close to X on t stage. The rays reaching such a point are shown as dashed lines in fig. 2 and it clear that in the cases shown in figs. 2*a* and 2*c* these rays are partially eclips only when the screen is at S_1 or S_2. In other words X' lies within the penumb when the screen is at S_1 or S_2 but not when it is at S_3. In practice it is rar convenient to insert the screen either at S_1 (because the condenser is norma very close to the stage), or at S_2 (because of the space occupied by the polariz

nat conditions necessarily approximate to those obtaining with the screen at nd the effect is confined to grains in a narrow penumbral region. Under the litions shown in fig. 2*b*, however, i.e. when the condenser is raised, it is clear X' lies within the penumbra even with the screen at S_3 so that the pen- ral region is of considerable width in this case: it can, in fact, be made to r the whole field of view if the condenser is sufficiently close to the stage. It st, therefore, to raise the condenser as high as possible when studying the ts on grains in different parts of the field, e.g. when distinguishing between oclase and untwinned basic plagioclase in a section or in grains mounted in am.

further point which appears from fig. 2*c* is that, no matter whether the n is placed at S_2 or S_3, X' lies in a region of greater illumination than X. In r words, although individual grains are illuminated from opposite sides in the cases, the dark and light sides of the field of view are not reversed, as is ly seen in fig. 3. It is therefore manifest that the light does not necessarily h the grains from that side of the field which appears illuminated.

is also to be remarked from fig. 2 that the rays reaching the different points X', &c., are derived from bundles of rays initially incident on the condenser in ly different directions. If it is desired to make observations at more than one t in the field of view it is therefore imperative that an extended source of nination be employed, and this can be achieved by the use either of the sky f a microscope lamp of conventional type placed as close to the mirror as ible. If the lamp is situated at any considerable distance it will not subtend a ciently large angle at the condenser and only a small region in the centre of ield will be illuminated. It is clear that when the condenser is in use inclining mirror cannot influence the obliquity of the rays reaching any given grain and only determine the part of the field which is illuminated.

e may summarize our conclusions by saying that if the Schroeder van der k method is employed on a microscope without condenser the oblique illu- ation should be obtained by removing the polarizer and swinging the mirror e distance to one side. This can be most effectively done if the mirror is fitted knuckle joint. If a condenser is fitted to the microscope it should be raised gh as possible and an extended source of light should be used. If a screen is inserted into the path of the light at any convenient point below the con- er, but preferably as close to the condenser as possible, unambiguous results be obtained. It is easy to remember that with the condenser raised, a crystal gher refractive index than the medium appears light on the light side of the . If, however, the condenser is lowered, ambiguities may arise and care in rpreting the observations is necessary. In the case of microscopes of the Dick , a screen inserted between the polarizer and the mirror is well above the ugate focus whether the fixed condenser is used alone or with the addition of upper part. The reversal of the phenomenon which occurs when the con- er is lowered cannot, therefore, take place with these microscopes.

A nomogram for the law of direction-cosines.

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[Read November 6, 1941.]

If α, β, and γ are the three angles between a line passing through the origin and the three rectangular co-ordinate axes, then the equation connecting them is as follows:

$\cos^2\alpha+\cos^2\beta+\cos^2\gamma = 1.$

This is the law of direction-cosines of a line.

Substituting $(\cos 2\alpha+1)/2$ for $\cos^2\alpha$, &c., we get:

$\cos 2\alpha+\cos 2\beta+\cos 2\gamma = -1.$

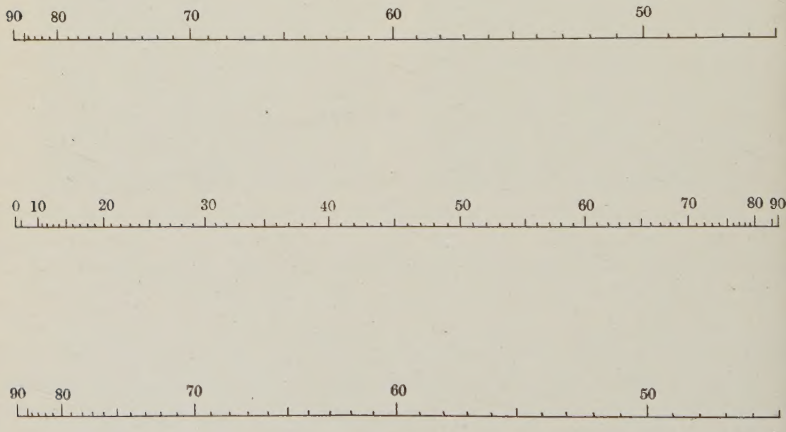

Fig. 1. Nomogram for direction-cosines. (Reduced to $\frac{1}{2}$.)

A nomogram for this equation is easily constructed. Three parallel lines of equal length are drawn at equal distances from each other (fig. 1). The first and third lines are graduated with the values of $\cos 2x$, from $x = 45°$ to $x = 90°$. The second line is graduated with the values of $(-1-\cos 2x)/2$, from $x = 0$ to $x = 90°$. A straight line drawn across the lines of the nomogram should pass through the three values of angles which will satisfy the equation of direction-cosines.

The nomogram should be drawn on Bristol board and a strip of celluloid with a straight line scratched on its lower surface should be used for the estimation of the angles. The nomogram can be used for a rapid determination of the third angle when the other two are known, or for checking the correctness of the calculated or measured angles.

I have found this nomogram very useful for checking the co-ordinate angles of the principal axes of the optical ellipsoid to a certain crystallographic plane of a

al, as measured on the Fedorov stage. The usual proceedure of plotting the ts of measurements on the Fedorov stage on a piece of tracing-paper placed e a stereographic net, is rather intricate and mistakes of recording are apt to . A nomogram of the direction-cosines equation is simple in use and would to check the figures at a glance. The nomogram can also be used for checking nterfacial angles between the face (*hkl*) and the faces (100), (010), and (001) rystals with a set of rectangular crystallographic axes.

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he chemical composition of leucoxene in Cainozoic bauxite from Boolarra, Victoria.

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[Communicated by Dr. F. L. Stillwell; read November 5, 1942.]

URING a petrological examination of samples of bauxite from Boolarra, in south Gippsland, Victoria, it was noted that some specimens of the bauxite, h is largely derived from Tertiary olivine-basalt, contained numerous grains llow-brown to amber-yellow leucoxene. The leucoxene is clearly pseudo-hous after ilmenite, residual particles of ilmenite being enclosed in many of eucoxene grains. Most of the leucoxene grains are opaque, but occasional s are translucent to transparent, though isotropic. Some of them show llel markings suggestive of cleavage, but probably a residual structure from eplaced ilmenite. In view of the highly aluminous nature of the enclosing there seemed some possibility that this mineral might be the little-known inium titanate, xanthitane. It was thought, therefore, that if a pure sample e mineral could be prepared, a chemical analysis would establish its identity. hen the bauxite was treated with 1 : 1 H_2SO_4, the gibbsite which formed the of it was quickly dissolved, leaving the leucoxene apparently unaltered in elatively small residue. An attempt to separate the leucoxene from this ue in bromoform was unsuccessful, on account of the fine-grained and ulent nature of the residue, which consisted chiefly of clay, amorphous silica, titanium oxide. When, however, the residue was transferred to a Haultain rpanner, it was found that a distinct concentration of the coarser grains of xene could be prepared. The concentrate was contaminated with a con-able amount of ilmenite and partially altered felspar. A sample of 1000 s of bauxite was then treated in 50 gram lots, first in sulphuric acid, and on the superpanner. The concentrate obtained was finely granular, and ble for separation in heavy liquids. Successive treatments in bromoform of fic gravity 2·889 removed all but a small amount of the felspar from the rate, which was then returned to the superpanner. Successive treatments ade on the superpanner, until no more ilmenite could be separated. oscopic examination revealed that ilmenite was still present in moderate

amount, so the powder was subjected to treatment with an electromagnet un only a minute amount of free ilmenite remained in it. Microscopic examinati at this stage showed that the leucoxene concentrate still contained a small pr portion of ilmenite, chiefly as unaltered residuals within the leucoxene grains. small amount of felspar was also present, but not in sufficient amount to mask t composition of the leucoxene in a chemical analysis. An attempt was made reduce the ilmenite content still further by stewing the powder for an hour 1 : 1 H_2SO_4, but no appreciable reduction could be detected. The amount almost pure leucoxene obtained at this stage amounted to about 0·18 gram, specific gravity 3·56. The refractive index of the translucent grains w determined in sulphur-selenium melts as 2·15±0·03, which is lower than that either rutile, brookite, or anatase. When roasted in air for half an hour at brig red heat, the leucoxene became uniformly opaque. The colour changed on roa ing from yellow to white with a tinge of buff.

The chemical analysis shown below (no. I) was obtained from a 0·1 gra sample of this powder.

	I.	II.
TiO_2	86·6	72·12
FeO	3·6	1·35
Fe_2O_3	—	0·50
SiO_2	1·2	24·49
Al_2O_3	0·5	nil
CaO	n.d.	nil
MgO	n.d.	nil
H_2O+	8·0	1·66
	99·9	100·12

I. Yellow leucoxene from Boolarra, Victoria.

II. White leucoxene, in Permian sandstones, Oklahoma. Silica derived from qua (F. Coil, 1933.)

The iron in the analysis is presumably derived from the residual ilmenite the leucoxene, which would therefore amount to about 7·6% of the samp The silica and alumina are derived from the felspar contaminating the samp The leucoxene consists, therefore, of hydrated titanium oxide, $TiO_2.nH_2O$. T result confirms that of Coil[1] as to the composition of leucoxene. Presumably water content of leucoxene is variable, since the sample of leucoxene analysed Coil (no. II above) contained considerably less water than the Boolarra leucoxe and had a correspondingly higher specific gravity of 4·17 (?), compared with 3 for the Boolarra specimen. The colour of the Oklahoma leucoxene analysed Coil was, moreover, white, as distinct from the pronounced yellow colour of Boolarra leucoxene.

[1] F. Coil, Chemical composition of leucoxene in the Permian of Oklahoma. Amer. M 1933, vol. 18, pp. 62–65. [M.A. 5–285.]

e on datolite and other minerals in a contact-altered limestone at Chapel quarry, near Kirkcaldy, Fife.[1]

(With Plate IX.)

By James Phemister, M.A., D.Sc., and A. G. MacGregor, M.C., D.Sc.
Geological Survey of Great Britain.

[Read June 5, 1941.]

HE Chapel, or Charlestown Main, Limestone horizon lies in the Lower Lime-stone Group of the Carboniferous Limestone Series. At Chapel quarry the lime-e is underlain by a thick sill of quartz-dolerite. The contact, however, is not sed but probably lies only a few feet below the quarry floor.[2] Other intrusions seen in the vicinity: a very thin dike of decomposed basalt, which connects a small 'float' of white trap, cuts the limestone about 30 yards north-east-ds of the point where the quarry crosses the Chapel road, and a small sill of ne-dolerite or teschenite occurs at a horizon about 100 feet above the top of limestone. In the quarry the limestone is about 60 feet thick. The contact-ration described in this paper is most evident near the base of the limestone and its extension laterally in the quarry has no relation to the outcrop of the dike. The alteration is therefore considered to be essentially connected with underlying, unexposed, sill of quartz-dolerite, and, as will be shown in the wing pages, has been effected by the action of hot solutions rather than by mal reconstruction.

ne specimens in which datolite was first observed were collected by Mr. D. lane, through the courtesy of Mr. William Black, during excavations under-n by the Charlestown Lime Co., Ltd., with a view to renewing operations at lime-works. The excavations, now abandoned, were made at the base of the rry face, 150 yards north-eastwards of the point where the quarry crosses the el road. Subsequently Dr. A. G. MacGregor and Mr. Haldane made a fuller ction of material to determine the extent of the alteration. The minerals rmined in the altered limestone are datolite, garnet (mainly grossular), olite, talc, and apophyllite. In the limestone forming the walls of the thin mentioned above much pyrite and a small quantity of blende are present. king of the limestone at Chapel quarry was stopped because fluxing took place ne kiln.

he limestone.—The Chapel Limestone is a grey compact crinoidal limestone type common in the Lower Carboniferous. Towards the base of the face in ei quarry mineralogical change is made manifest by the development of a e or pale green lustreless aggregate as flecks and wisps disseminated through grey limestone, as concentrations of irregular size and shape, and as thin s parallel to the bedding. Some of the last are sharply bounded against the limestone, others show passage into the limestone either by gradual change

[1] Communicated with the permission of the Director, Geological Survey and Museum.

[2] J. K. Allan and J. Knox, The economic geology of the Fife coalfields, Area II. Mem. Surv. Scotland, 1934, p. 24.

in the proportions of carbonate and aggregate, or by way of a zone of veins a strings of aggregate. In one specimen, S 34826,[1] replacement of crinoid columna and shell fragments by the aggregate can be readily observed in hand-specime Thus the macroscopic relations suggest that the aggregate may partly represe shaly intercalations, but certainly is in part a metasomatic introduction.

Where the grey limestone is free of the white or pale green aggregate it h usually a slightly indurated appearance suggesting contact-metamorphism of very low order. Under the microscope a wide range of texture and mineral co position is observed. In some specimens the shapes of fossils are well preserv (S 34819), but the matrix of fine calcareous debris and the walls of the more delica fossils may be recrystallized in finely granular calcite. In others the limestone converted to a mosaic of calcite grains with complete destruction of fossil shap There is every stage between these extremes of texture, but there is no regul relation of the degree of recrystallization to the proportion of new silicates nor the vertical distance from the quartz-dolerite sill. For example, granoblas recrystallized limestone occurs up to at least 30 feet from the base of the quar face, and recrystallized limestone of similar texture occurs in patches near t base of the quarry face among fossiliferous limestone in which there is lit textural change. These granular patches usually show by transmitted light brown coloration which is discharged when the powdered rock is roasted and probably due to disseminated bituminous or carbonaceous particles. Simi brown calcite mosaic occurs as infilling in the chambers of foraminifera and polyz and within ostracod bivalves (S 34444). These observations perhaps indicate th calcite is easily recrystallized at comparatively low temperatures in the presen of hydrocarbons residual from the decay of organisms, the less volatile hyd carbons being trapped in the growing calcite.

In thin sections of the limestones the fine aggregate is seen in all proportio from small interstitial tufts of fibres or flakes to extensive accumulations. So of the latter, as already recognized in hand-specimen, appear in thin section a to represent layers of calcareous shale. The aggregate in these is extremely fin divided and is almost opaque and enwraps numerous organic remains includi crinoid columnals, often showing trabecular structure, ostracod and other she and Productid spines (S 34445). In other specimens where the fine aggregate abundant it is distributed in irregular manner through the limestone and repla the fossils. The crinoid columnals are usually replaced peripherally, but the alte tion has sometimes proceeded throughout the whole plate (S 34826 and pl. I fig. 3). The fine aggregate is sometimes pectolite, but in most specimens steatite. Distinction in thin section is based mainly on the different appearan of the straight, sharply bounded fibres of pectolite and the softer, less regu laminae of steatite. The individual crystals of the two minerals are, howev often so small that distinction in thin section is not possible. Pectolite has b observed as the main constituent of two very thin, sinuous, and impersistent ve (S 34445A) in one of which the pectolite is locally replaced by apophyllite.

Garnet (pl. IX, fig. 4) is the next most abundant silicate and occurs in varia proportion through the limestone up to 24 feet above the quarry floor. It show tendency to be abundant where there is much fine aggregate, both of the pecto

[1] The numbers refer to specimens and corresponding slides in the Sliced Rock Collectio the Geological Survey and Museum.

steatite types. Datolite is more abundant in the purer calcite portions (pl. IX, . Its vertical extension seems to be much less than that of garnet, and it has been observed at a level more than 8 or 10 feet above the quarry floor. Both t and datolite are present abundantly in the type of limestone which retains t fossil shapes as well as in the granoblastic limestone. Even within the of a thin section the content of these minerals is, however, very variable. mode of occurrence of the datolite and garnet in the texturally little altered ome is interesting. They appear indifferently in the fine matrix, inside the ot shells, within the single crystals composing the crinoid columnals, and seem ve developed with special ease along the axial canal of the columnals. A re- able phenomenon is the replacement of gastropod shells by aggregates of e garnet (pl. IX, fig. 2), and it is suspected that the walls of foraminiferal olyzoan chambers are replaced in like manner, but the structures, being very te, have been too greatly obscured for definite identification (S 34445B).

e observations recorded above prove the permeation of the rock by solutions ing silica, boric oxide, and soda (perhaps also alumina and magnesia) in a tion chemically active but productive of little physical reconstruction. The n for the fixation of silica and alumina as garnet in the shells is not apparent. ses of the hard parts of marine organisms show that in general the sum of and alumina is less than one per cent.,[1] and these oxides must therefore have carried into the shells. Local concentration of alumina and silica leading to itiation of centres of garnet crystallization may perhaps have been produced lm of clay were adherent to the shell. Garnet occurs also as a narrow rim unding small nodules of chert (S 34445B2).

ophyllite is a later mineral than those already described and occurs in veins regular patches (pl. IX, fig. 5) indefinitely bounded against the rest of the The relations indicate that apophyllite has replaced both calcite and fine gate, the grossular and datolite remaining as inclusions in the plates of yllite. Though apophyllite is the scarcest of the minerals under description e only one of the suite which has already been recorded from Chapel quarry. le states that it is found as fine crystals associated with elaterite and dolomite.[2] he following paragraphs notes on optical and other properties of the minerals ven. As already stated the fine aggregate is in some specimens pectolite, but st it is steatite.

tolite is found most abundantly in the small extension of the quarry west of hapel road, where it occurs disseminated through the limestone, and also as earthy-looking masses several centimetres in length, and as coatings on planes. The mineral forms microscopic bundles of sharp-edged fibres which fficiently parallel to afford a biaxial positive figure from cross-sections of the e (S 34812). The individual fibres are about 0·005 mm. thick, but larger s reaching 0·03 mm. in thickness are fairly common. The refractive indices ined by immersion in oils are $\alpha \leqslant 1{\cdot}595$, $\gamma = 1{\cdot}632$. When heated in C. the mineral is partly soluble, partly replaced by opaline silica, and partly ted. It gives a strong sodium coloration to the Bunsen flame. Mr. F. A. er confirmed the identification by an X-ray powder photograph which dentical with that of pectolite from Paterson, New Jersey.

1. W. Clarke and W. C. Wheeler, Prof. Paper U.S. Geol. Survey, 1922, no. 124.
2. F. Heddle, Mineralogy of Scotland, 1901, vol. 2, p. 82.

Talc (*steatite*).—Optical tests on the fine aggregate from the specimens in t main quarry proved very difficult. The aggregate is softer and more matted, t individual fibres less clearly defined than is the case for the pectolite aggregate the quarry west of the road. Highest and lowest refractive indices of appro mately 1·580 and 1·535 were determined for the principal constituent of the agg gate in several specimens, and in view of these values and of the mode of occurren of the material in the manner of argillaceous intercalations it was thought t mineral was a kind of sericite or illite, possibly a sodic variety, since the analy of the limestone shows Na_2O 1·82%. Mr. F. A. Bannister, to whom we th appealed, proved by X-ray methods that the aggregate is steatite, the pow photograph proving identical with that of crystallized talc. A partial chemi analysis by Mr. C. O. Harvey showed SiO_2 58·0, MgO 29·4, CaO 1·2, $Na_2O + Li$ 0·2, and K_2O 0·1 %, yielding $SiO_2 : MgO = 4 : 3$ as required for talc. The aggrega nevertheless, is not greasy to the touch like talc, perhaps on account of the c siderable quantity of minute garnet included in it. Though talc is the main c stituent of the earthy-looking material in the main quarry, pectolite is present some specimens, and in a slide, gelatinized and stained primarily for the detect of apophyllite, pectolite is observed to be stained slightly (S 34445B).

The two main constituents of the fine aggregates have thus been identifi but it is certain that other silicates are present in smaller quantity. They can detected when the powder is immersed in suitable oils and also in certain sm areas of the thin sections where apophyllite has replaced the most of the f aggregate. Tiny straight-extinguishing fibres of a mineral, perhaps antigor perhaps pectolite though the birefringence seems too low, persist in the apophyll The minor constituents perceived by immersion in oils include pyroxene as t prisms with high refractive index and highly inclined extinction, and sm sharp-edged prisms showing straight extinction, positive elongation, and refr tive indices approximately 1·605 and 1·625, properties which would agree w anthophyllite.

Garnet forms more or less perfect dodecahedra of diameter usually about 0·0 0·1 mm., rarely as great as 0·2 mm., and often very minute. Most of the crys have a turbid appearance which appears to be due to the presence of a broken otherwise discontinuous coating of andradite, of refractive index ranging upwa from 1·825 to over 1·845. The main garnet is grossular with n 1·740 on the aver but varying slightly above and below this value. Mr. F. A. Bannister kin offered to make a powder photograph of this mineral also and found as the u cell dimension 11·85 ± 0·02 Å., a figure agreeing well with other measurements grossular, notably G. Menzer's measurement of 11·84 Å. The andradite skin p duced no effect in the X-ray photograph. It is worth noting that there is transitional zone between the grossular and the andradite and that the relatio therefore not one of zoning in the usual usage of this term. It was observed that the garnets which show perfect crystal faces are entirely grossular with any andradite coating.

Datolite forms rounded grains which are usually about 0·1 to 0·2 mm. in diam but reach up to 0·4 mm. (S 34821) and they tend to occur in small groups (pl. fig. 5). The grains sometimes have an irregular outline as if corroded. mineral is scarcely attacked by cold dilute HCl and is therefore easily con trated by dissolving away the calcite matrix. In hot acid, however, it is rea

inized and the powder moistened with HCl yields a pronounced boron ion to the flame test. The optical constants were determined as α 1·625, 3, γ 1·670, 2V 73·5°, negative, and are almost identical with those measured cLintock on datolite from the Lizard.[1]

e refractive indices were determined by immersion in oils, and the optic angle is the average of values ranging from 72° to 74·5° measured on five ent grains by use of the universal stage. Mr. F. A. Bannister has made an x powder photograph of the mineral and states that the pattern is identical that of datolite from Seisser Alpe, Tirol.

ophyllite was first detected in an unfinished section which had been covered glycerine. The perfect cleavage, which is not seen in balsam mounts, was conspicuous. The mineral gelatinizes readily with acid and its fairly wide bution is most easily observed by treating the thin section with acid and ing the gelatinized mineral. Refractive indices were determined on an un-ed section, washed clean of balsam, as α (or ω) 1·535, γ (or ϵ) 1·537 or 1·538. mineral is optically positive, but we were unable to decide whether the figure ved with the conoscope was that of a uniaxial or of a biaxial mineral. The ction is straight, α is parallel to the cleavage and the latter is normal to ns which give the highest polarization colour (an anomalous brownish-

.

emical composition.—By courtesy of the Director, Macaulay Institute for Research, we are able to reproduce an analysis made by Mr. A. Muir of a osite sample of the limestone, prepared from two datolite-bearing specimens. f these was collected near the level of the quarry floor, and the other at a of approximately 6 or 8 feet above the floor. The material analysed is thus bulk-sample of the quarried rock.

...	...	21·72	MgO ...	...	1·90	H_2O- ...	...	0·41
...	...	0·40	CaO ...	...	38·82	P_2O_5 ...	...	0·08
...	...	4·26	Na_2O ...	...	1·82	CO_2 ...	...	26·68
...	...	1·00	K_2O ...	...	0·25	B_2O_3 ...	...	2·00
...	...	0·09	H_2O+ ...	...	n.d.	FeS_2 ...	...	0·21
							Total	99·64

e amounts of B_2O_3, K_2O, and MgO shown by this analysis would correspond ctively to datolite 9·15, apophyllite 4·8, and steatite 6·0 %, figures which for apophyllite, but seem rather high for datolite and low for steatite ve to the evidence of the thin sections. The content of soda would correspond 5 % of pectolite, the only soda-bearing mineral we have been able to identify. such a proportion is probably realized in parts of the limestone in the small y west of the road, it appears to be very high when referred against the ce of the thin sections of limestones from the part of the main quarry which ied the specimens for analysis. Either some other soda-bearing mineral is nt or a local concentration of pectolite must have occurred in the sample ed. A rational analysis in terms of the minerals calcite, datolite, grossular, pectolite, and apophyllite cannot be calculated from the analysis with a ble degree of approximation.

mary and Conclusions.—In the limestone at Chapel quarry the minerals

[1] W. F. P. McLintock, Min. Mag., 1910, vol. 15, p. 412.

datolite, grossular, and steatite are of contemporaneous formation, pectolite partly contemporaneous with datolite, and garnet partly somewhat later, wh apophyllite is definitely later than these minerals, enclosing or replacing the These silicates occur as constituent minerals of a limestone which is textural little altered; garnet and datolite appear among the calcite infilling well-preserv shells and in the canals and plates of crinoids; shells are replaced by garnet, a pectolite replaces shell fragments and crinoid columnals without destruction the fossil shapes. It is evident therefore that the minerals were developed throu the agency of fluids capable of intimate penetration through the rock, chemical very active but productive of only a low degree of physical reconstruction.

With the exception of steatite, the silicates are richly calcic, and with t exception of grossular they contain the elements of water. For their formati introduction of much silica has been necessary and minor but notable amour of boric oxide, soda, potash, and probably fluorine have been required to for datolite, pectolite, and apophyllite. It is possible that the alumina and subor nate ferric oxide of the garnet were originally present in the limestone in the for of slightly ferruginous clay substance. The metasomatizing fluids must therefc have been essentially solutions of alkali silicates, initially sodic and finally potass and containing in the early stages boric oxide.[1] The temperature of the solutio was probably low, since they reacted to form hydrous minerals and effected lit physical reconstruction. The development of grossular under such circumstance affords striking confirmation of the fact, already well recognized, that this speci of garnet forms with ease in aluminous limestones subjected to thermal met morphism.

The formation of a pectolite-like mineral from calcite by the action of h sodium silicate solution was realized experimentally by Lemberg in 1885, and t formation of apophyllite by the action of potassium silicate solution on calci was carried out by Churin between 1913 and 1918.[3] Lemberg recorded the pect lite-like mineral as formed also by the action of sodium silicate on datolite. Tl transformation, though suspected in specimen S 34812, was not convincing observed in the Chapel quarry limestone.

Datolite is best known as a mineral from cavities and veins in basic igneous ro and in mineral deposits and hydrothermal veins associated with the contacts limestone and igneous rock.[4] As a constituent of the altered country-rock it h however, been recorded only rarely, and in Britain up to the present only from calc-flinta associated with greenstone in the aureole of the Dartmoor granit In the Caucasus low-temperature metasomatic replacement of limestone datolite occurs at Pyatigorsk,[6] where Senonian limestone is changed by the acti of hot springs, of temperature 46°C. and containing 0·00344 gm. per litre of B_2 into compact datolite-bearing hornstone in which foraminifera are preserv

[1] The presence of boron in the residual glass of tholeiite has been stated by Dr. F. Walke conclusively proved but to an amount under 1%, Min. Mag., 1930, vol. 22, p. 375.

[2] Cf. J. H. Taylor, Min. Mag., 1940, vol. 25, p. 545. (Grossular associated with analcim

[3] See G. W. Morey and E. Ingerson, Econ. Geol., 1937, Supplement to vol. 32, no. Bibliography items nos. 31 and 86.

[4] For example, E. V. Shannon, Proc. U.S. Nat. Mus., 1924, vol. 66, art. 2, and 1925, vol. art. 28. [M.A. 3–204.]

[5] K. Busz, Neues Jahrb. Min., 1899, Beil.-Bd. 13, p. 126.

[6] P. Tchirwinsky, Zeits. Krist., 1929, vol. 70, pp. 260–261. [M.A. 4–181.]

the Caucasus also datolite-bearing rocks have been described as a result of ction of boron-rich emanations or solutions on limestone in contact with lac- ns of trachyliparite.[1] Pseudomorphs after datolite in lenses of limestone within s altered by diabase have been found at Hopewell mine, Pennsylvania.[2] paragenesis of datolite at Chapel quarry indicates that here also the conditions rmation were of comparatively low-temperature hydrothermal type.

e occurrence of steatite in the limestone is puzzling. Like the other silicates nt it is a hydrothermal mineral but, in contrast to them, it is a purely nesian silicate. Three hypotheses of its formation may be mentioned: (i) the ite may represent argillaceous material into which magnesia has been intro- d and from which alumina has been removed; (ii) and (iii) the steatite may sent magnesium carbonate present (ii) as dolomite in dolomitized limestone i) as a primary constituent of the limestone. The first hypothesis involves somatic introduction of magnesia which is of all the oxides the one least to be effluent from a quartz-dolerite. Moreover, there is no indication of the dary formation of an aluminous mineral from the alumina removed according is hypothesis. If, as seems more probable, the magnesia were present in the tone prior to its hydrothermal alteration one of the hypotheses (ii) and hould be true. Though dolomitized limestone is certainly present in Chapel y it appears to be resistant to the hydrothermal changes and none of the minerals of the limestone appears in the dolomite. It is, moreover, a compact ular rock showing scarcely a trace of fossil structures, but these are abundantly nt in the steatitic limestone. It would appear, therefore, that the steatite eveloped from magnesia present as a primary constituent of the limestone. rding to Clarke magnesia may occur in this manner either as a direct pre- ite from shallow marine waters in which organisms are decomposing or as a ituent of the hard parts of organisms. These have been proved to contain ng proportions of magnesium carbonate up to 11, 11, 14, and 8·6 % in the of polyzoa, foraminifera, echinoderms, and brachiopods respectively.[3] If the esia of the steatite has been so derived there is no indication of the fact in the bution of the steatite, for this mineral shows no tendency towards preferen- placement of, for example, crinoid remains. Again, if the steatite represents ary magnesium carbonate the dense, almost monomineralic aggregates which ms show that wide redistribution of magnesia and lime must have been in- d at the time when hydrothermal solutions were active. A further hypothe- ay be mentioned. Stevensite, a mineral similar to talc in composition, has recorded as due to the action of magnesian solutions, derived from weathered t, on pectolite.[4] In the Chapel limestone, however, there is no reason to ve that the steatite is derived from pectolite nor that it owes its formation athering solutions.

conclusion, we wish to express our thanks to Mr. F. A. Bannister, Deputy er, Natural History Museum, for his confirmatory X-ray work on datolite, ilite, and grossular, and for his identification of steatite.

M. Kurman and Z. M. Usacheva, 1937. [M.A. 7–442.]

Vaux, jr., Proc. Acad. Nat. Sci. Philadelphia, 1927, vol. 78, p. 17. [M.A. 3–121.]

W. Clarke, Data of geochemistry. 4th edition, Bull. U.S. Geol. Surv., 1920, no. 695,

H. Glenn, Amer. Min., 1916, vol. 1, p. 44. [M.A. 1–31.]

Explanation of Plate IX.

Datolite, grossular, pectolite, and apophyllite in the Chapel Limestone, Chapel quarry, Kirkcaldy, Fife.

The numbers refer to the Rock Slide Collections of the Geological Survey and Museum. photographs are taken by ordinary light.

Fig. 1. S 34444A3. Right: a normal type of limestone showing a crinoid columnal and sh fragments in turbid fine-grained calcareous debris with patches of granular calcite stain deep brown. Left: a more granular limestone showing relics of organic structur numerous clear grains of datolite, and many individual crystals and small aggregates turbid grossular which appear in the photographs as black spots. × 12.

Fig. 2. S 34445B3. A small gastropod shell replaced by grossular. Clear datolite grains a numerous among granular calcite and form a cluster just to the right of the centre. ×

Fig. 3. ED 1269. A longitudinal section of a crinoid columnal is completely, and a tran verse section is peripherally and axially, replaced by fibrous pectolite. Small crystals grossular occur in the pectolite felt at the bottom of the photograph. × 10.

Fig. 4. S 34444A2. Clear roundish grains of datolite and small semi-opaque dodecahed of grossular are numerous among granular calcite. × 46.

Fig. 5. S 34445B. The dark vein and patches are apophyllite (gelatinized and deep stained). The patches of apophyllite in the top left quadrant of the photograph a associated with an unusually large aggregate of clear grains of datolite. × 22.

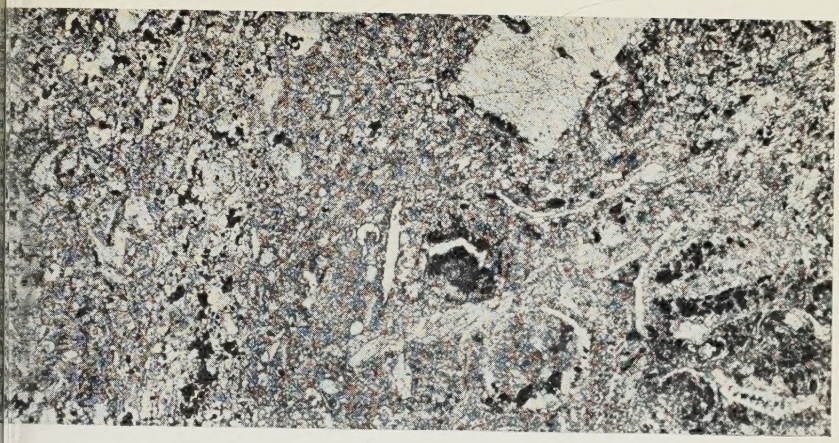

Fig. 1

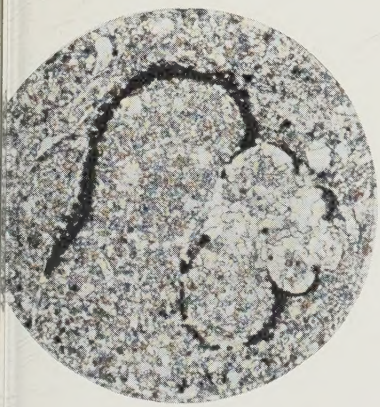

Fig. 2

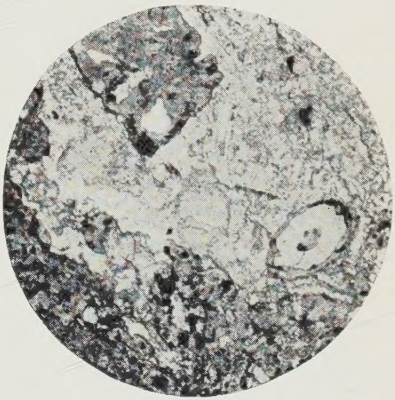

Fig. 3

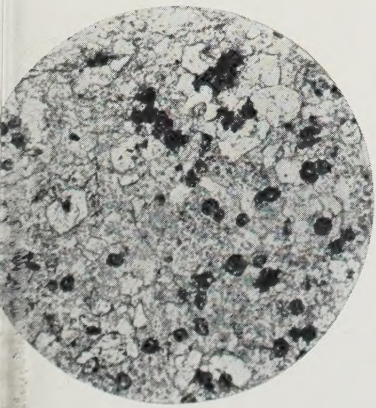

Fig. 4

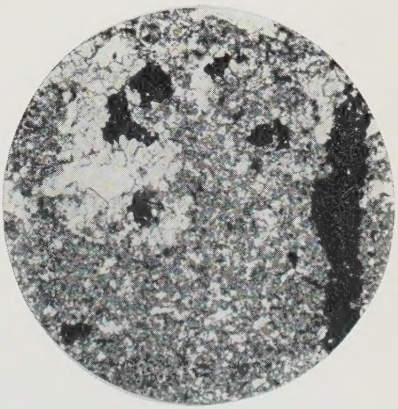

Fig. 5